SUPPLEMENT.

The Mining Journal,

RAILWAY AND COMMERCIAL GAZETTE:

FORMING A COMPLETE RECORD OF THE PROCEEDINGS OF ALL PUBLIC COMPANIES.

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HE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

STEEL MAKING—Mr. BESSEMER AND Mr. MUSHET.

In the Mechanical Section a paper, by Mr. R. Mushet, "On the reatment of Melted Cast Iron, and its Conversion into Iron and teel by the Pneumatic Process," was read by the Secretary, in the bsence of Mr. Mushet. After some introductory remarks, describ-ng a patent taken out by the late Mr. David Mushet for the manu-acture of refined iron direct from the blast furnace, the paper stated hat the defect in this process was that the waste of metal was ex-essive, owing, no doubt, to the surface action of the blast upon the nelted iron for a prolonged period. The iron, however, was decar-onised, so as to be in the condition of crude cast steel, but it was oo highly oxygenated to be forged into bars of commercial value. This, the writer believed, was the first experiment ever made; but n the year 1850 he made some further experiments, with some highly blown refined iron from the Parkend Ironworks, in the Forest of Dean, and found that when alloyed with manganese this refined metal could be forged into sound bars of very hard steel—too hard for any practical purpose, but nevertheless solid, and free from seams or flaws, indicating that if the iron could be sufficiently decarbonised whilst in this melted state, steel of marketable quality might be ob-tained by simply adding some metallic manganese to the decarbon-ised metal. In the autumn of 1856 Mr. Henry Bessemer read a paper at a meeting of the British Association, held in Cheltenham, which, whilst it filled the scientific as well as the practical world with won-der, did not in the least surprise him (Mr. Mushet), except in the circumstance of its being possible to maintain a tuyere beneath a heavy column of melted cast iron. What he had considered impos-sible had actually been accomplished by Mr. Bessemer, and the first great advance towards rendering steel as cheap as iron had been made. After describing Mr. Bessemer's process of operation, the paper stated that when Mr. Bessemer read his paper he foresaw all the difficulties he would have to encounter from the oxygenation of the iron, although he knew that the remedy was simple and at-tainable, providing a suitable metal could be found at such a cost, and in such quantities, as would render its use practicable on a large scale. At last he selected the metal manganese, and his first experi-ment was with some Bessemer metal, prepared at the Victoria Iron-works from hematite pig iron. The experiment was made in small crucibles, containing only a few ounces, the Bessemer metal being melted in one crucible, and the spiegeleisen in another. The melted contents of the crucibles were next mixed, and a small ingot was cast. This ingot was forged into a bar of excellent cast steel, which was doubly welded, and made into a chisel, and it was found, for all practical purposes, to be cast steel of fair average quality. He then extended the scale of his experiments, and operated with steel melting pots, each containing from 40 to 50 lbs. of Bessemer metal, and melting the spiegeleisen in small crucibles. The most complete success resulted from these experiments, and Mr. S. H. Blackwell having subsequently supplied him with a small blowing engine, ca-pable of maintaining a blast of 10 lbs. pressure per square inch, he operated upon quantities of melted cast iron of from 500 to 800 lbs., and with similar success, the Bessemer metal being wholly freed from unsoundness, red-shortness, and other defects, which had precluded it being forged or rolled into a marketable product. He secured his invention by letters patent in 1856, but this lapsed in 1859, owing to the non-payment of the stamp duty of 50*l.*, through some unaccount-able oversight. His invention thus became public property, and he was thus deprived by the accident of all remuneration for it, which every person practically acquainted with the manufacture of Besse-mer metal would admit to be of immense value. He spoke, no doubt, as an interested party, and his opinion was, therefore, open to criti-cism; but he ventured to submit that an invention such as that de-scribed in his last patent placed all who had benefited by its use under a moral obligation to recognise his claims to remuneration, for, although by the accident of the non-payment of the stamp duty his invention became public property, he still thought that that accident ought not to debar him from receiving the reward to which he was justly entitled.

As Mr. Bessemer had been so pointedly referred to by Mr. Mushet, the President gave that gentleman the privilege of opening the dis-cussion. Mr. Bessemer, who was received with loud applause, then addressed the Section. Referring to Mr. Mushet's statement, that although he had no legal claim he had a moral claim upon him, he stated that he was one of those who looked upon a moral as much greater than a legal claim. He contended, however, that Mr. Mushet had even no moral claim against him, and was proceeding to support his argument by reference to specifications, when the President ex-pressed the hope that the speaker would confine his remarks to the practical subject referred to in the paper. Mr. Bessemer at once assented to this, and gave an exceedingly elaborate and interesting account of his own system of manufacturing steel, and showed the vast importance that branch of industry had assumed since his patent had come into working operation. By the old system 40 lbs. of steel was the largest mass of metal operated upon; but by the Bessemer process as much as 25 tons could be converted into steel in one heat-ing. It had superseded iron wherever large castings were required—such as ordnance of large size, locomotive and marine engine cranks, rails, &c. He mentioned, as showing the superior durability of steel rails over those of iron, that at the station at Camden Town, at a part of the line over which all the traffic passed, a steel rail was placed on one side of the line, and an iron rail on the other, and that 17 faces of the iron were worn away while the first face of the steel rail was still in working order. Steel rails put down four years ago were still in working order. The first cost of steel rails was, of course, much greater than that of iron, but compensation was found for this in the greater durability.

Lord Wrottesley protested against the controversial matter that Mr. Mushet had introduced into his paper. Such papers, in his opi-nion, should only contain scientific facts.

Mr. Galloway, of London, showing an inclination to introduce more of the personal element, was instantly called to order. He then suggested that the "rival houses" of the Bessemers and the Mushets should unite, so as to work their respective patents, to the mutual benefit of both parties; but the novel proposal was received as a good joke by the Section.

Mr. Bessemer, in reply to questions, stated that the steel rails, when worn out, were not valueless, as had been represented, for at an expense or 2*l.* per ton, they could be converted into bars worth 18*l.* per ton. His process had produced a wonderful effect on the price of steel, for while under the old system of manufacture steel, and that of inferior quality, was never sold to any extent below 36*l.* per ton, tens of thousands of tons were now sold at 18*l.* per ton.

Mr. I. L. Bell said he attached the utmost importance to a satis-factory solution of the question, whether it was possible to use, in the making of steel by the new process, iron containing a notable quantity of phosphorus. By far the greater proportion of iron used in this country contained more or less phosphorus. He would allude particularly to the recent important addition to the iron-producing powers of this country. He alluded to Cleveland, where they all knew that the iron ores produced, from their peculiar composition, yielded more or less phosphorus. It was, therefore, important to know whether, at no distant date, they should be able to produce steel from the metal likely to occupy a similar position to that re-sulting from Mr. Bessemer's process. He himself was engaged in some experiments with Mr. Mushet, in Newcastle-on-Tyne, about 1846, for doing that which Mr. Mushet claimed in his paper.

Mr. Bessemer, in reply, said that steel made from iron contain-ing a large proportion of phosphorus was not very good. Up to the present time he had adhered entirely to the use of hematite. If the manufacturers of the iron referred to by Mr. Bell would employ lime containing no fossil remains, and no phosphoric acid, they would find their iron to be better than it now was. If they also washed the coal used they would produce iron worth 20s. a ton more than was the case now. They must also abandon the practice of putting the cinder into the blast furnaces. The manufacturers of steel could certainly not deal with material so contaminated in the first instance.—The discussion on this paper was very lengthy, and brought out several points of interest.

THE COAL QUESTION.

In the Geological Section, Sir R. I. Murchison read a paper "On the various Tracts in England and Wales in which no Productive Beds of Coal can reasonably be looked for." He said the ingenious sugges-tion of Mr. Godwin-Austen that coal measures might be found under London was formed on a well-considered, general, and comprehen-sive view, as well as upon much close observation. He urged that, as coal was worked under the chalk at Valenciennes, and had been found to a certain extent in recent sinkings under the cretaceous deposits ranging westwards towards Calais, it might further extend across the Channel, and be found under similar cretaceous rocks on the South of England. The theory, which from the recognised re-putation of its author attracted considerable attention, had recently been largely and boldly applied by Mr. Hussey Vivian, M.P. Re-flection upon the order and nature of the rocks which surround the south-eastern coasts of England, whether on the coast of France, the Channel Islands, or the western, midland, or north-eastern counties of England, having led him (Sir R. Murchison) to adopt an opposite conclusion, he begged to offer some observations in explanation of the view which he took—that no productive coal measures could be looked for in the counties of Essex, Kent, Sussex, Middlesex, Hert-fordshire, Hampshire, Oxfordshire, Suffolk, Norfolk, and the East-ern Counties. To this hopeless list, in which Nottinghamshire was happily not included, must necessarily be added all the numerous tracts wherein rocks older than the carboniferous rose to the surface, as in the greater part of Wales and Herefordshire, in all of which coal could not of necessity be found. Let them first test the value of the data afforded by observations in France, which had led him to the application of the above theory to the South of England. It was quite true that, inasmuch as beds of coal of considerable dimensions were worked at Valenciennes at once beneath the chalk, all the in-tervening formations which exist in many other parts of the world were there omitted. That fact simply indicated that at Valenci-ennes the coal-bearing deposits had formerly been elevated, so as to constitute ancient lands, and had not afterwards been depressed under the sea during all the periods in which the Triassic, Liassic, and Jurassic formations were accumulated in other tracts.

Those carboniferous strata at Valenciennes constituted a portion of the southern edge or lip of the great coal basin of Belgium. The portion of those coal strata which existed in France, and which at Valenciennes dips at a high angle to the north to pass into Belgium, had been also found to have a lateral extension on the strike for a certain distance to the west, beneath the cretaceous rocks—*i.e.*, point-ing towards the British Channel. For, by trials and through those cretaceous rocks and over-lying deposits, those same coal strata had been found to extend beyond Bethune; but they there thin out to a narrow band, which diminishes to a wedge-like mass directed to the W.N.W. The western limit of the richer portion of that field had been definitively proved by the fact that in all the borings which had been made to the east of the village of Flechenelle, Devonian lime-stones, schists, and grits alone had been reached, the coal being thus completely cut out. His conclusions were especially drawn from a good statistical and mining map recently prepared by able civil en-gineers, for the Compagnie de Nœux et Vicoigne, as laid down on the maps of the Depot de la Guerre, as well as from his own obser-vations in the Boulonnais. In that map every concession or grant of a right to sink for coal (in number exceeding 200) was marked, the results of each sinking, and the depths being regularly given. All the practical French geologists were of opinion that the coal basin of Valenciennes and Belgium terminated, as far as any productive value went, a few miles to the west of Bethune. As the coal mea-sures thus thinned out as they approached the British Channel, though some traces of poor coal had been found extending to near Calais, so they had a clear demonstration in the tract immediately to the south of that town, by reason of the natural outcrops in the Boulon-nais, that no productive coal measures were superposed to the car-boniferous or mountain limestone. Judging from the gradual de-terioration of the carboniferous rocks as they approached the French side of the Channel, he held that there could be no good reason to hope that better conditions could reasonably be looked for through-out the southern coasts of England. Judging, also, from the well-ascertained data that the secondary rocks of the western and central parts of England which lie beneath the chalk—the trias, lias, and oolites—thinned out in their extension as they inclined to the south-east, was well proved by the memoirs of Mr. Hull; still it was by no means improbable that the part of the oolitic series which appeared in the cliffs to the north of Boulogne might be persistent under the cretaceous and Wealden rocks of Sussex and Kent.

The question, then, was what would the fundamental rock prove to be in those districts if it should ever be searched for? Reasoning from such data, and the visible outcrops in the Boulonnais, his infer-ence was that if not in part jurassic, they would probably prove to be either a thin band of carboniferous limestone without any produc-tive coal, or, still more probably, Devonian rock only. So far, then, he agreed with Mr. Austen. Proceeding to trace the line of older rocks which separated the south-eastern from the south-western coun-ties, they saw the Devonian rocks of the Quantock Hills, in West Somerset, without a sign of anything carboniferous; and when they advanced northwards to the Mendip Hills, the phenomena they there met with were, it seemed to him, indicative of the hopelessness of seeking for any productive coal measures between those hills and the Straits of Dover; for, on the west, the mountain limestone forms the outward eastern girdle of the great Somerset and Bristol coal basin. Throughout a distance of about 35 miles, that which was the unproductive bottom rock of every coal-bearing strata in the South of England and Wales—the carboniferous limestone, with traces only of millstone grit—was everywhere and at once surmounted on the east by thin courses of New Red, or by the Lias and Oolitic formations. It had been mentioned to him that an exception occurred to those re-lations in the neighbourhood of Frome, where the unproductive mountain limestone was said to exhibit an axial form, with coal measures on two sides. If the coal so worked be not on the eastern flank of limestone, but only on the southern side, and is not seen to dip to the east, and so pass under the Lias and Oolitic beds, his reason-ing was unaffected. So much for nearly the whole length and breadth of the country lying to the east of the outermost or underlying band of all the carboniferous rocks of the South of England and Wales, including the Forest of Dean to the east, of which the non-existence of any coal measures was rendered still more striking, because, in addition to a rim of mountain limestone wholly unproductive of coal, the Old Red Sandstone and Silurian rocks are interposed in the Tort-worth country, and are there immediately covered by the Lias and Oolite. The data and reason might indeed be applied to the country extending from that town northwards, and to all the valley of the Severn and the Cotswold Hills, as well as to all the country lying to the south-east of Cheltenham. Who, for example, would speculate on the chance of finding productive coal to the north of Newent, in Gloucestershire, when it was known that on the west the only outcrop was in the miserably poor coal tract which occurred at Newent, and exhibited its final termination on the north, by the rise of the Silu-rian and older rocks? Equally absurd would it be to look for coal in many other parts of the Severn valley of Gloucester and Worces-ter, which lie to the east of the Malvern Hills, where the New Red Sandstone lies upon the crystalline and other rocks of that range.

Extending that view, it seemed to him that the Malvern Hills on the south-west, and Charnwood Forest on the north-east, each com-posed of rocks of much higher antiquity, form the salient promon-tories of the old coast line, to the east of which, respectively, there could be little or no hope of finding productive coal measures. Even if it should be suggested that the southern ends of the Staf-fordshire and Leicestershire fields might have a south-easterly con-tinuation, which is by no means forbidden, still the enormous accu-mulation of superposed rocks would on any reliable estimate be out of the question as to the working of coal. On the other hand, there could be little doubt that vast supplies of coal would eventually be worked to the north and west of those fields, so far beneath the Per-mian and New Red Sandstone formations in the Midland Counties wherein the coal measures have been raised to the surface by the up-heaval through those younger deposits. Thus, the Red Sandstone tracts between Wolverhampton and Coalbrookdale, in Cheshire, be-tween the Flintshire coal and the great Lancashire field, and over vast areas similarly circumstanced, there could be little doubt that coal would ultimately be worked, a view which he (Sir R. Murchison) strongly advocated 30 years ago, and which was published in his "Silurian System." But to return to the consideration of the case, as respects the wide area in which London lies, let them proceed due north from Reading, on that line the first ancient rocks met with were those of Charnwood Forest, which were admitted to be of Cambrian or infra-Silurian age. To the west of those, indeed, lay the Leices-ter coal tract, as well as other coal fields of the central counties to which he had alluded; but to the east nothing was seen but secondary rocks, from the New Red Sandstone and Lias to the oolites and cre-taceous rocks. Who, then, with such an outcrop to the west, would sink for coal in any of the counties lying to the east or south-east of Charnwood forest and Hart Hill? The recent well-sinkings at Har-wich to procure water had, it seemed to him, completely solved this portion of the problem. There the trial ended in the discovery be-neath 1025 feet of cretaceous rocks of a hard slaty rock, with possi-donia of the lower carboniferous limestone, evidently older than any coal-bearing stratum. That fact, it seemed to him, showed conclu-sively that the great Belgian coal field did not extend eastward to England. To widen the application of the inference as to where coal could be reasonably sought for, he might extend the reasoning he had employed to the whole of Leicestershire and the East Riding of Yorkshire. On this head he would first allude to the south side of the Valley of the Tees, a tract which he had long known extending from Croft to Middlesbro', where the New Red Sandstone was covered by the debritous and northern drift.

At the last-mentioned place Mr. Vaughan, an ironmaster, being desirous of obtaining subterranean water for the working of his en-gines, sunk an artesian well to the depth of 1800 feet, and at length

reached a bed of rock salt subordinate to the New Red Sandstone—in fact, without reaching even to the surface of the magnesian limestone, through which the deep coal pits of the Earl of Durham are sunk to the extreme depth at which coal has hitherto been worked in that county. If, then, the coal should be prolonged to the south of the Tees, and should pass under the Vale of Cleveland, and the hills of the eastern moorlands, what would be the depth at which it would have to be sought, by passing through the Oolites and Lias, in addition to the New Red Sandstone and magnesian limestone? On this point it would be observed that we had not as yet any proof that the Durham coal field was prolonged to the south of the Tees between Stockton and the mouth of the river. The works that had been opened out by passing through the magnesian limestone are situated at many miles to the north of the Tees, and we must first know that the coal can be found under the intermediate country, and under the New Red Sandstone of Darlington, before we can reasonably speculate on the existence of it beneath the Vale of Cleveland, even should there be adventurous persons who might try for it at a depth of 4000 or 5000 feet beneath the subjacent secondary rocks. But whilst he admitted that there was a possibility of the Durham coal field being thus extended to the south-east beneath all those thick overlying deposits, they possessed geological data which in his opinion showed that no really valuable coal seams were to be found in the Vale of York and the central portion of the North. On the banks of the Tees, west of Darlington, the productive coal measures were entirely wanting, and valuable vegetable, or coaly, matter had never had an existence in the tract extending from Barnard Castle, on the Tees, to the south of Harrogate.

After some remarks relative to the experiments being made in the pits of Mr. Webb, of Newstead Abbey, Sir Roderick said he should give no opinion whatever on the probable duration of coal until the Royal Commission had completed its surveys. His sole object was to exclude from the reasoning on English coal fields those hypotheses which, however ingeniously put, were, in his opinion, negatived by a fair reasoning on the data they possessed. When they excepted 21,800 square miles, or nearly one-half of England and Wales, necessarily, as consisting of rocks older than the coal measures, and in which no coal could possibly be found; when he had shown those *a priori* reasons for setting aside the hypotheses that productive coal fields might exist under our southern and eastern coasts, they had simply to proceed to form the best approximate estimate they could of the amount of coal left in the fields which they had so long worked. It seemed that the existence and possible future supply of coal for all practical purposes had an apparently defined limit, ranging over little more than an eighth part of England and Wales, or an area of about 6000 square miles. He declined to express any opinion on the duration of the coal pits of Great Britain until a close survey had been carried out with a view of determining that point. He fully appreciated the anxious desire felt by all those who were interested in the future welfare of the nation to have this subject fully and fairly enquired into, the more so as he had, in conclusion, to announce that, by the last enquiry made by Mr. R. Hunt, the officer of the Government establishment under his (Sir R. Murchison's) direction, last year's consumption of coal reached the portentious quantity of nearly 100,000,000 tons.

Prof. PHILLIPS made some general remarks on the question of the duration of coal in this country. He stated that the total quantity of coal available for use was about 80,000,000,000 tons. The present consumption, according to Mr. Jevon's calculations, was at the rate of 100,000,000 tons per year, and, supposing that gentleman's theory to be correct, that this consumption would increase at least 3 per cent. every year, he (Mr. Jevons) was not so far wrong in computing that the coal would be exhausted in 110 years. By assigning a limit, however, to the maximum consumption, and placing that limit very liberally at 300,000,000 tons per year, it would be found that 350 years would elapse before the exhaustion of the coal fields. (Applause.)

The PRESIDNT requested Sir William Armstrong to address the Section on this important question; Sir William, however, declined to do so, stating that he could not speak as an authority on the purely geological part of the question, and that being a member of the commission appointed to enquire into the question, he did not think it advisable to commit himself to any expression of opinion.

Mr. GILLAN thought it impossible to come to any definite conclusion on the subject in this Section, seeing that economical as well as geological considerations were involved in it. It must not be forgotten that the expense of bringing the coal to the surface of the earth was rapidly increasing, and that the freightage from distant places was as rapidly decreasing. An important economical question was how long it would be possible to bring coal to the surface of this country at less expense than it could be brought from other lands. (Hear and applause.)

The discussion having been continued by Mr. JOHN DAGLISH, who referred to the fact of many old collieries having been opened, and large supplies obtained from them; and by Mr. MOGRIDGE, whose experience of the South Wales collieries enabled him to state that several of the proprietors had adopted a plan of working which effected a great practical saving without diminishing the yield—Mr. WEBB mentioned that he was at present conducting important operations in the North Riding of Yorkshire, with the view of ascertaining whether any coal existed on his property there.

Mr. BRADLEY could not join in the cry about the probable exhaustion of our coal fields. If Mr. Webb's operations proved a success, he believed sufficient coal could be found in the Vale of Yorkshire to serve the people of this country for 500 or 600 years. (Laughter and applause.)

Sir RODERICK MURCHISON replied to some remarks that had been made regarding the details given in his paper; and, referring to Mr. Webb's operations, said that if he succeeded everyone would rejoice, whilst if he failed he would still have conferred a great benefit on science.

COAL MINING IN NOTTINGHAM.

In the Geological Section, Mr. EDWARD HEDLEY read a paper "On the Sinking of Annesley Colliery." The Annesley Colliery is situated close to the railway from Nottingham to Mansfield, and about eleven miles from the former and six miles from the latter town. Its geological position is on the New Red Sandstone, and nearly two miles east from any other coal workings. The seam of coal intended to be won is that locally known as the Top Hard coal, and which is now being worked at the Portland, High Park, Hucknall, and Cinderhill Collieries, all in the immediate neighbourhood. The estimated depth of this coal at Annesley Colliery is about 400 yards. The sinking of the shafts commenced in January, 1865, but was shortly stopped for a few weeks for the erection of the necessary pumps and pumping-engines. Since then the sinking in one shaft has continued unremittingly. When finished, it is intended that each shaft shall be 13 feet diameter. The following description of the strata sunk through will be better understood by referring to the section of the shafts and strata:—The first measure sunk through was a deposit of loose dry sand and gravel, 6 ft. in thickness. This, and a bed of sandstone below it, 62 ft. in thickness, comprise the New Red Sandstone sunk through. This lower bed consists of a soft friable sandstone of a light red and white colour. In one shaft it was divided by beds of strong red marl, but in the other these were absent, and the bed formed an unbroken rock. As the area of surface drained by this rock is not extensive, the quantity of water met with in sinking through it was inconsiderable.

The next stratum is the red marl, forming the upper part of the Permian measures. This marl is 27 feet in thickness, it is of a dark red colour, with lumps of white intermixed. It is worked extensively in the neighbourhood for the manufacture of common building bricks, and when properly ground and tempered it makes good bricks. Very little water was met with in this marl, but when the sinking had approached within 6 feet from the bottom of it, the water in the magnesian limestone below it broke up the bottom, and rose up the shaft several yards; by continuous pumping this, however, was lowered again, and the shaft sunk to the limestone. A large quantity of water had now to be pumped, three lifts of pumps, each 12 inches in diameter, were constantly pumping, discharging altogether about 1500 gallons per minute. The first bed of the magnesian limestone formation is a freestone, 18 feet thick. It it very hard at the top for about a foot deep; in this are numerous small veins, containing small quantities of spar, lead ore, and iron pyrites. Below this the stone is much softer, and is light red and white mottled in colour. Below the freestone stratum there are several thin beds of pure limestone, divided from each other by beds of shale or bind. In one of these thin seams of limestone, which is 1½ ft. thick, and at a depth from the surface of 121 ft., there was found a quantity of lignite, in the original form of branches of trees. These were destroyed in blasting up the limestone, which completely enveloped them, and the lignite preserved has since gradually crumbled to small prices.

A similar occurrence of lignite in limestone of this nature is not known to the writer. Nothing more of a fossiliferous character was found in passing the Permian measures, although a careful examination from time to time was made for that purpose. The limestone shales underlying the limestone, and forming the lower part of the Permian measures were upwards of 80 ft. in thickness. They mostly consist of strong, compact shales of a light grey colour; the bottom part is soft, and of quite a marly character. About two miles north-west from this colliery the limestone shales crop out to the surface, showing their junction with the coal measures, and it is there seen that the lowest stratum of the Permian formation is a bed of conglomerate about 2 ft. thick. This has been supposed to represent the lower New Red Sandstone. No trace of this conglomerate was found in sinking the shafts at Annesley; for in passing the marl at the bottom of the shales the coal measures were at once proved by the abundance of their characteristic fossils. The dip of the Permian strata is uniformly to the east, and about 1 inch per yard. The dip of the new Red Sandstone could not be accurately ascertained. Only small quantities of water were met with in the lower part of the limestone and in the shales, so that the pumps were dispensed with, and the water drawn in the sinking buckets.

The following is a detailed section of the strata, as sunk through in the No. 1 shaft:—

NEW RED SANDSTONE.			
Sand and gravel	6 ft.	0 in.	
Land rock	31	1	
Red clay	2	0	
Sand rock	14	1	
Red clay	2	1	
Grey sand rock	13	3	= 68 ft. 6 in.
PERMIAN FORMATION.			
Marl	26 ft.	9 in.	
Freestone and limestone	17	11	
White marl	0	6	
Bind or shale	6	1	
Limestone with lignite	1	8	
Bind or shale	4	6	
Limestone	4	4	
Bind or shale	1	4	
Limestone	3	8	
Bind or shale	63	11	
Grey rock	0	8	
White marl mixed with red ochre	2	6	
Bind or shale	3	6	
Soft yellow bind	2	8	
Stone bind	9	8	= 149 8
Total			218 ft. 2 in.

The coal measures are found in their regular order dipping nearly due east, and, so far as has been proved, conformable with the Permian measures. The usual alternating strata of sandstone, shales, thin coals, and fire-clays comprise the coal measures hitherto passed through; they are compact, and impervious to water. The deepest shaft is now 200 yards deep, and has passed through several thin seams of coal, none of which, however, are workable. As the sinking progressed, both the shafts were lined with strong cast-iron tubbing, which, when wedged, formed a water-tight casing. It was found necessary to tub the shaft thus to a depth of 98 yards; below this point very little water is found in the strata, and the shaft is walled with ordinary brickwork, 9 in. thick.

The writer has nothing to communicate in this paper beyond the foregoing facts, but before concluding he desires to call your attention to the importance of this sinking, with regard to future coal mining operations in the county of Nottingham; as it is, with others, a conclusive proof of the practicability of sinking through the water-bearing stata of the New Red Sandstone and Permian formations, covering a large area of coal measures in the east part of this county.

STEAM BOILERS.

Mr. HENRY DIRCKS read a paper "On Steam Boiler Investigation." For more than a century the employment of the steam-engine has been attended by accidents more or less disastrous to life and property occasioned by the sudden bursting of the boiler from some cause or other never distinctly defined, so that to the present day it continues to be enveloped in so much mystery, that practical men are unable as much as ever to satisfy each other on this important matter. Every investigation leading to discussion on this subject at once shows the unsettled state of opinion, whether on the part of the public, the engineer, or the manufacturer.

Among the many causes to which steam-boiler explosions are attributed, we may mention:—1. Deficiency of water in the boiler; 2. Overheating of boiler-plates; 3. Unnatural strain on the rivets; 4. Imperfectly manufactured, or over-worn or corroded plates; 5. Deposits of salt, sand, mud, or scales of carbonate or sulphate of lime, &c.; 6. Collapse of internal tubes or flues; 7. Over-loading or fastening down of the safety-valve, or its becoming accidentally fixed. Other causes are not wanting, but which relate principally to obvious negligence and recklessness.

Such is the present state of the matter as affecting the class of accidents indicated, happining to stationary, locomotive, marine, and all steam-boilers whatever. At the same time, it may be as well to mention here that, as a mere matter of fact, it is nevertheless well known to be possible to construct certain kinds of boilers, and to adopt modes of generating steam, that may be declared to be absolutely free from the danger of any serious explosion. Such boilers, and novel modes of generating steam, are, however, unfortunately attended with many practical difficulties, when desired for use on the large scale of an extensive manufacturing establishment. It is sufficient for the present purpose merely to state thus much of plans not wanting in ingenuity, but which are simply inapplicable for general purposes. No boiler of its kind, whether stationary, locomotive, or marine, can be too simple in construction; complication of parts being invariably fatal to economy in working. As an object of strength, it would be well if all boilers were made of either copper or steel, but here again economy suggests the use of iron. Strength, again, with consequent safety, might be obtained by increased thickness of metal, but we should thus obtain one desirable end at the loss of another—economy, in the use of a thick plate boiler. Therefore it follows that we must sacrifice something of the safety to be thus obtained to provide a sufficiently efficacious steam-generating vessel, whether for the mill, the rail, or the ocean.

We have no occasion here to go into the history of boiler construction, or to suggest improvements, but only to consider the circumstances connected with the explosion of steam-engine boilers, assuming them to be of generally approved construction, for it more generally happens that the destroyed boiler has been many years in use than otherwise, a sufficient proof of no serious mal-construction. We assume, then, the enquiry to relate to the cause of explosion in a boiler, perhaps one or two, or more boilers in connection, which has suffered the terrible consequences of an explosion.

Every judicial enquiry would take into consideration one or all of the previously named ordinary causes of explosions, and we can all well imagine the variety and conflicting character of the statements of each authority on such occasions. How are we to reconcile this conflict of opinions on a point which is, unfortunately, no great novelty in our manufacturing districts, among, too, the best informed and most intelligent of all classes of manufacturers? Manchester has its association for recording facts on this very subject, and yet even in Manchester contrariety of opinion prevails on this important subject. The very fact that we have made no progress in this enquiry during at least 100 years may possibly be accounted for by our having hitherto made the investigation as one purely mechanical. Now, it is obvious that this enquiry, being partly mechanical and partly chemical, confusion must continually ensue so long as the one investigation is pursued independent of the other; and, indeed, on no other principle can we account for our present imperfect knowledge of a subject which every day's experience proves to be of growing importance, as affecting life and property. We have hitherto, perhaps, been too prone to bridge over the difficulties involved in this enquiry by contentedly attributing every cause of explosion to instances of negligence, either in the manufacture of the iron or the boilers, or in their use by the proprietor employing them, or to stokers or labourers about the premises having charge of their management. However true in many instances such decisions may be, it must not be overlooked that they do not offer an answer to every example of explosion, and to rest satisfied with such a course of explanation alone, although it might satisfy a judicial enquiry, could only serve to suppress the scientific investigation of phenomena, to the real nature of which engineers may fairly claim at present to be utter strangers.

The mechanical consideration of this subject is one with which practical engineers are so intimately acquainted that it will suffice briefly to enumerate the following:—The uniform use of wrought-iron; the occasional employment of staffordshire and Bowling iron in the same boilers; systems of staying boilers; improvements in tubular or flue boilers; improvements in valves, gauges, and feed apparatus; with improved furnaces and modes of firing. In all details affecting these departments of construction every engineer is mainly agreed. But on the possibility of explosion from over-heated plates, and whether electricity or hydrogen plays any part in the terrific explosion of a steam-engine boiler, whether ammonia, or sometimes sulphur are eliminated during the combustion with a destructive effect on boiler plates; whether cold draughts of air suddenly admitted to a furnace can occasion a dangerous expansion and contraction of the boiler-plates; whether hydrogen, oxygen, or nitrogen affect the safety of the boiler, all these, and other kindred subjects, particularly as to the probability of decomposing water into its constituent elements in large steam-boilers, are a *terra incognita* to the practical engineer, such considerations being wholly beyond the sphere of his usual studies and pursuits.

The experiments of Mr. William Fairbairn, C.E., Sir William Armstrong, and others, afford evidence of the necessity of making experiments on a large scale, conducted with every possible assistance for securing accuracy on points of interest, whether mathematical, mechanical, or chemical. Experimental results might be obtained under proper arrangements for the bursting of a boiler of approved construction, with every appliance deemed requisite for security, under ordinary circumstances. And, again, a similar boiler might be tried with a presumed defective boiler-plate, and then subjected to a destructive test to ascertain what results would follow. Also, boilers might be tested with clear, salt, or muddy calcareous waters, to arrive at some practical results in regard to their use. But it is evident that such a course of experiments being once established an infinity of trials would suggest themselves, and the results could not fail to be of the highest interest to the public, the manufacturer, and men of science generally.

Mr. W. FAIRBAIRN said it was most important that every possible endeavour should be made to prevent the explosion of steam-boilers. An association had been established in Manchester for the prevention of such accidents, and they had collected a number of facts relating to them. The only effectual precaution that could be taken was to have frequent periodical inspection of the boilers. Similar associations should be established in other towns. He did not approve of a system of boiler insurance, as it offered a premium to a man to blow up his boiler.

Mr. GALLWAY attributed the explosion of boilers to electricity.—Mr. BRAMWELL said that the principal reason of the explosion of boilers was because they were designed and built by persons who were ignorant of the principles upon which they should be constructed. He thought that the peculiar appearances presented in some boilers called "scoring," might be due to the effect of galvanic action.—Mr. HUGHES, who had been one of the inspectors of boilers under the Manchester Association, attributed the explosion of boilers to carelessness. The only way to prevent such accidents was to have the boilers periodically inspected by competent inspectors.—Mr. DIRCKS, in reply, mentioned the case of the Carron Works, which had been in operation for upwards of 100 years, without any of their boilers exploding, as an example of the effect of care in the prevention of accidents of this description.

The thanks of the meeting were then accorded to Mr. Dircks.

A large party visited Mr. North's coal fields, at Nuttall, where a most hospitable welcome was accorded. In an outbuilding we were asked to take off hats and coats, and equip ourselves in brown holland jackets, with towels tied round our heads like turbans. Some of the ladies had got as far as the jackets, when the word was passed that they could not be taken down the pit. The disappointment was great, but they bore it good-humouredly, and another excursion on the surface of the earth was planned for them. When equipped in the brown holland and turban, and each provided with a short broomstick, the gentlemen looked qualified to take part in a pantomine, and burst out laughing at each other's odd appearance. Soon we reach the bratticed shaft, and the lift begins to take down six or seven of the party at a time into the ugly yawning gulf below. A circle of miners, or mining population, surrounds us, and is free with criticism and a little banter. "Suppose there should be a smash-up!" one of them said. "Well, I'd rather an accident happened to them than to our own kith and kin," a woman replied. It was natural enough, but she need not have said so just then. For the bucket, or lift, went down into the dark well-like chasm so quickly that you almost turned giddy as you looked. Suppose the rope should break, and a cargo of *savans* be brought back to the surface in little pieces. The pit was some 250 yards deep. Some of the party step into the lift with rather pale faces, but they cannot turn back now for very shame. "Stand fast! Hold tight! Don't put your arm or hand outside the bars! For goodness' sake, put that stick inside! You'll have your arm broken, Sir, to a certainty, if you don't take care!" These were amongst the injunctions and warnings thus given to us by the experienced miner who arranged us in the cage. And then came the cry of "pull up!" to which they in the engine-house duly responded. The cage was lifted up a few feet, and then down it went at once with a sudden dive into thick darkness. During the first few seconds you had a horrible sensation, as though somebody had seized you on the top of Salisbury steeple and had hurled you into space. A sea-sick man has much the same sensation when the vessel goes down into the hollow of the sea. Strange to say, though, this feeling soon wore off. The motion was rapid, but not disagreeable, and you could not tell whether you were going up or down. In three or four minutes—the cage is lowered much more quickly when the miners descend—you are not sorry to touch the ground. A strange scene is then before you. Each man is furnished with an oil lamp, and in the gloom the party look like so many fire-demons. There is no protection for the lamps, but Nuttall is too well ventilated to allow the collection of any fire-damp; so without danger of explosion, and under good guidance, we walk along the wet, sloppy ground for a few hundred yards until we come to twenty or thirty coal trucks, worked upon a tramway with an endless rope by a steam-engine at the far end of the pit. Crouching down in these trucks, we presently find ourselves bowling steadily along through the coal measures. Sometimes the coal has been all won; sometimes we came to a fault, where the coal broke away and had to be sought for again by the patient miner. Often the roof was arched completely over with brick; but more frequently it was supported at the sides by massive wooden pillars. So we went through some three miles of galleries, riding or walking, heard a short description by the manager, Mr. Fowler, and saw the furnace, the air-shaft, and the steam-engine at work. The Nuttall Colliery is one of the most extensive in England, having four miles of underground communications. A powerful engine, centrally placed, works the trains of wagons by means of an endless rope running along the ground midway between rails, to which rope an apparatus resembling a sugar tongs admits of the wagons being clipped on or off at pleasure. There was hardly any water, and, as was stated in reply to enquiries, very few fossils are found in the mine. A sudden turn in the road was accounted for by a reminiscence very creditable to the engineering of the mine. Some years ago a break or fault was discovered in the vein of coal which suddenly disappeared, and, as was afterwards ascertained, leapt up 70 ft. How to reach it again was a problem anything but facile of solution; the managers, however, calculated that by continuing to work upon the level, but turning nearly at right angles to the former gallery they should meet the vein where it dipped again, and this estimate was justified by the result, though, of course, there was a long intermediate interval of profitless tunnelling. During the description, one visitor asked how much coal was produced per annum in the pit. "Why, that gentleman may be an income tax collecter," called out another visitor; whereupon the black mine echoed with laughter. Everywhere the galleries were well ventilated; the more distant workings may not be so, but the air-current was occasionally so strong that it blew out the lamps. Now and then we came upon a grimy miner, or one of the stunted, dirty ponies which live and die in the pit. When we had tired ourselves by exploring the mine, and were as grimy as miners and as hungry as hunters, the signal of return was given, and after due time we were all hauled up again safely into the blessed sunlight.

The visit to the extensive colliery works of Messrs. Barber, Walker, and Co., at Eastwood, was no less successful. What is called High Park Pit No. 1 was the mine allotted to be explored, and the arrangements made for the safe descent and intelligent guidance of the visitors were perfect. A number of ladies went down into the pit, where the works also are on a very large scale, no fewer than 500 persons and 40 horses being employed in the mine. At Riddings the shaft is not vertical, but is an inclined plane, starting with an inclination of 1 in 3, and proceeding at an incline of 1 in 9. The miners often walk down this shaft to their work, but the visitors are not permitted to do so. At Annesley the pit is a new one, not yet finished; but here, too, both ladies and gentlemen descended the shaft to see how such shafts are made. The shaft is on ground not usually supposed to cover coal, and shows the faith of its proprietary in the newer ideas of science on this subject. But I hear it said that a much bolder experiment is to be tried before long by the sinking of a shaft 7 miles or so east of Nottingham, 8 miles from the edge of the present coal field, which shaft will go 1000 ft. through the lias before it penetrates the strata which usually lie just above the coal.

One party visited the Erewash Valley. A 20 miles ride by "Midland" brought the "Riddings" party to the extensive iron and coal works of Messrs. Oakes and Co., on the Derbyshire side of the valley. The Pye-bridge station was reached about half-past 2; and, unable for the nonce to disregard their usual custom, the excursionists formed "sections," one taking the road to the colliery, the other proceeding to the ironworks. Mr. Oakes had received the visitors, and with the utmost courtesy had informed them of the best mode of making the inspections. Section "No. 1" soon reached the "pit," and made their subterranean excursion much more easily than their brother excursionists above mentioned, this pit being reached by an inclined plane. The cable was checked at intervals so that they might examine the various strata superposed on the coal measures. Having penetrated about 800 yards into the crust of the earth, the coal measure was reached, and the explorers left their carriages. The coal was found to be at that point about 3 ft. in thickness and hard in quality, being known as Derbyshire hard coal. Section "No. 2" had in the meantime visited the smelting-furnaces. The entire process was explained, and all that could make the inspection instructive and interesting was done. The most important matter to which this section was directed was a blast-furnace recently blown out, and which had been in operation 54 years. A large portion of its lower surface was encrusted with a coating of plumbago, from 1 in. to 3 in. thick, and to this circumstance the attention of chemists was chiefly attracted.

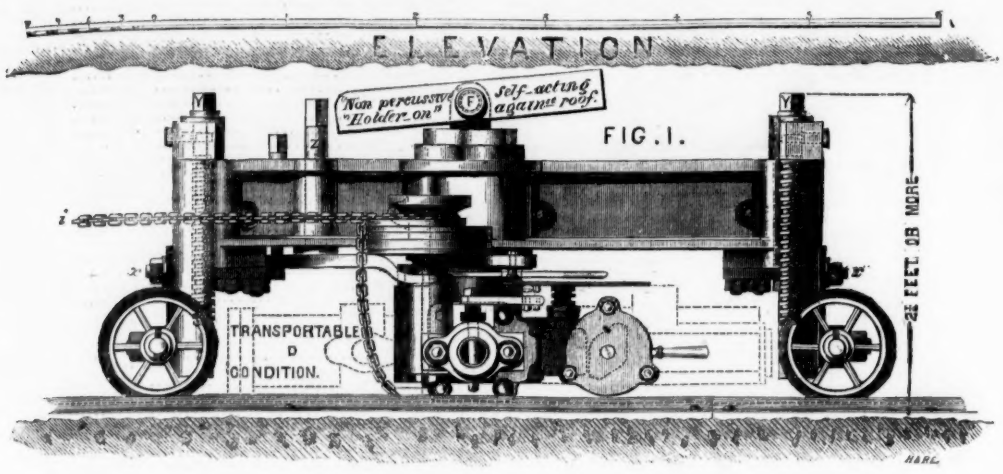
At the *soiree* in the Working Men's Exhibition Building, a most attractive article was a platinum apparatus and metallurgical preparations, sent by Messrs. Johnson, Matthey, and Co., of Hatton-garden: near this was a pure platinum ingot, which was much noticed, also a specimen of pure distilled magnesium, weighing 124 ounces, and some iridium alloy for heavy ordnance, welded by the oxy-hydrogen process, and some turnings of the pure magnesium metal. Running along for several yards is a somewhat wonderful model of a steam-engine, said to be worth 1000*l.*; near this piece of mechanism reposed an instrument of war in the shape of Whitworth's 2-pounder howitzer. Specimens of coal may seem to the uninitated in science rather peculiar, but amongst the show of minerals were pieces from Kimberley, Oakenthorpe, Church Gresley. Cornish iron ore, copper ore, and marble, were in abundance, finally culminating at the end of the table in some very singular exhibitions of steel-work, cast-iron, &c. Mr. Gale explained the principle of his breech-loading revolver, and also his well known composition for preserving gunpowder against explosion. Some of the curiosities of mechanics attracted a great deal of attention. Chief amongst these were a hydraulic mining machine and a magneto-electric machine, which promises great things. As at present, however, machines of this last class consume as much zinc per horse-power as a steam-engine requires of coal, it is scarcely likely that the system now in use will be supplanted.

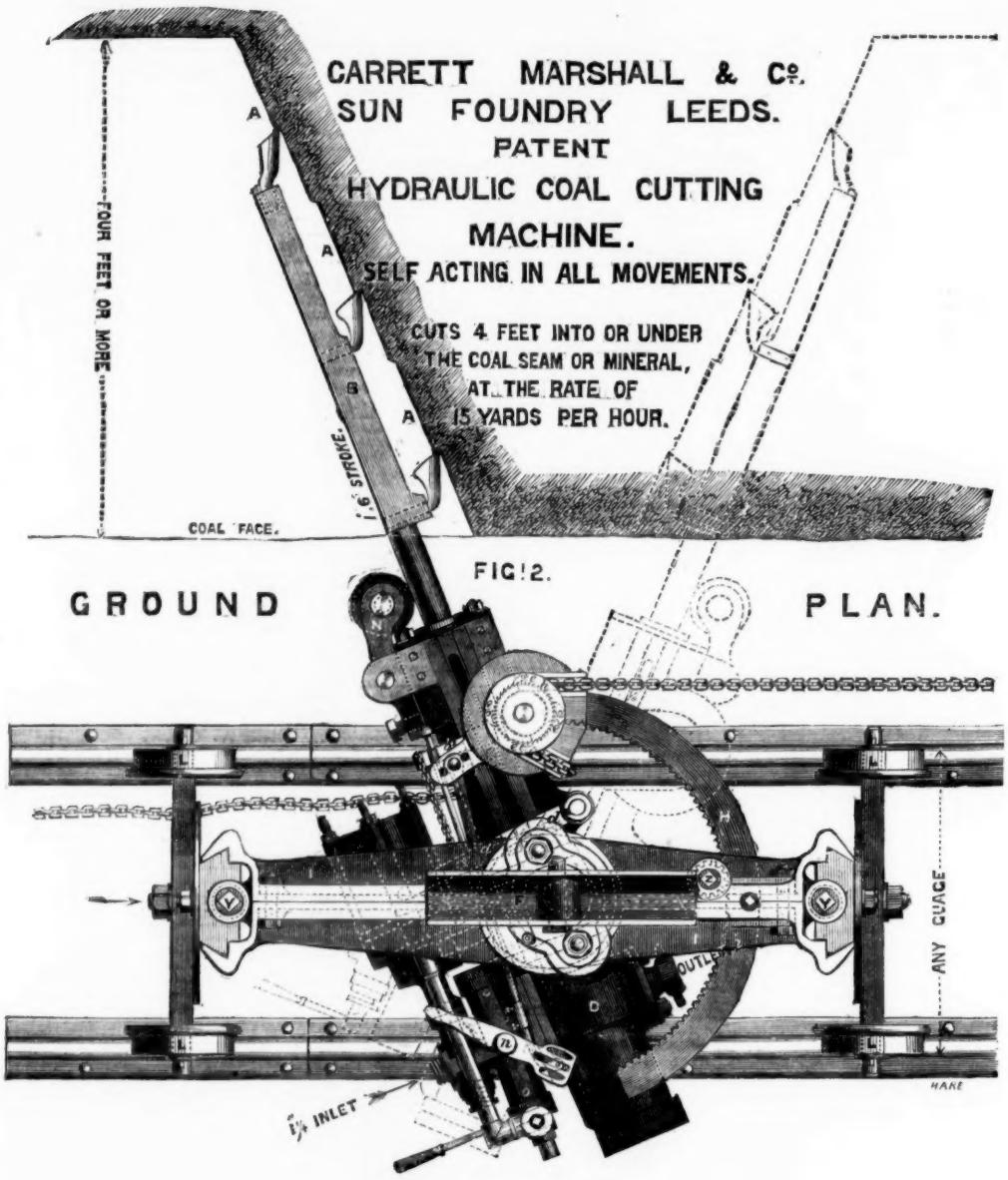
Dr. LE NEVE FOSTER related his discovery of a curious lode or mineral vein, containing pebbles, in New Rosewarne Mine, Gwinear, Cornwall. The peculiarity of this lode is that it is a brecciated lode, containing rounded pebbles. A crack appears to have opened underneath a bed of gravel or shingle, pebbles and fragments of rock fell into the crack, and were cemented by chlorite, tinstone, and other minerals. In the subsequent discussion, Prof. Ramsay, LL.D., F.R.S., said that lama bones had been found in a mineral vein in South America, at a considerable depth. He added that the processes of formation of the lode as described by Dr. Le Neve Foster implied an enormous lapse of time. Mr. W. Pengelly, F.R.S., said that he had seen, in the collection of his friend, Mr. Robert Were Fox, of Falmouth, a pebble from a copper lode. It had been broken in half, and then the two pieces connected together. Mr. John S. Enys, of Enys, had also mentioned somewhat similar cases to him. As no objection was raised to Dr. Le Neve Foster's views, he had but little to say in reply. He said he perfectly agreed with his friend, Prof. Ramsay, with regard to a vast lapse of time being required for the formation of the lode.

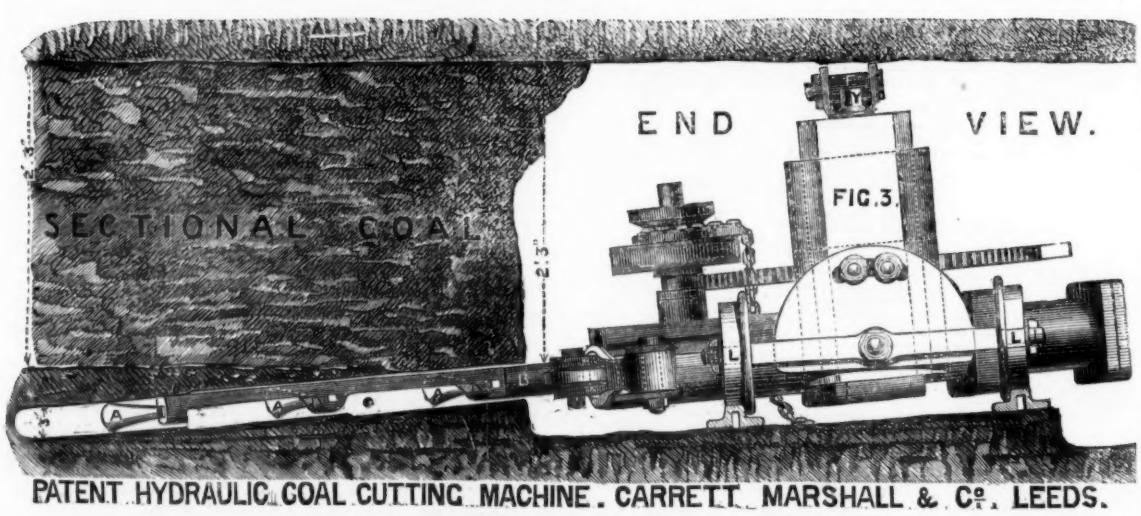
Mr. GEORGE SENIOR read a paper "On the Diminution of Accidents in Coal Mines since the appointment of Government Inspectors:" it was stated that the results of the application of the Acts of 1850-55 relating to the general working, management, and inspection of mines, had been to diminish very largely the loss of life amongst the mining operatives, and especially in the case of explosions, wherein the saving of life amounts to nearly 50 per cent., and in accidents in pit shafts, where the loss of life had been reduced 46 per cent. The loss of life in 1864, in raising 9278 millions of tons of coal, was one in every 354 persons employed, and only one life was sacrificed in raising each 110,000 tons of coal.

HYDRAULIC COAL-CUTTING MACHINE,

SELF-ACTING IN ALL MOVEMENTS.







PATENT HYDRAULIC COAL CUTTING MACHINE. CARRETT MARSHALL & Co. LEEDS.

This automaton machine or "iron man" is of three-horse power, and cuts at the rate of 15 yards per hour, 4 feet into or under the coal or mineral at any height or angle, and at "once going over," using thirty gallons, and making fifteen strokes per minute, at about 300 lbs. pressure; the cutting tools displacing only 3 inches of the coal or mineral so undercut or holed. The machine will ascend any gradient, and is suitable for "dip" or "rise" levels, and will force its own waste water along 2-inch pipes back to the place where the pressure was made, and it is adapted to cut right or left. It weighs 1 ton, and is applicable to the gauge of any mine, and, with its cutter bar removed, is easily transported from place to place. The cutting tools are of sheer steel, are easily removed and replaced after grinding on the flat face. There is no percussive action or injurious wear and tear, no noise, dust, or sparks when working, and the apparatus holds itself down on rails during the penetrating cut of the tools. One man and a boy are the necessary attendants. The incompressible water transmits the power given to it faithfully any distance through 2-inch wrought-iron gas pipes, tested to 500 lbs., necessary to work one machine; the flexible pipe will also stand the same pressure, and the water is used over again, as in the Bramah press, its quantity being only what is necessary to fill the circuit of the pipes.

SELF-ACTING COAL-CUTTING MACHINE.

The following paper was read before the British Association, at Nottingham, by Mr. W. E. CARRETT, engineer, of Leeds:—

In the general detail of mining operations the cutting away of the under portion of a valuable seam or bed of mineral, to facilitate its subsequent removal, is at all times one of the most labourious and difficult operations, and is often effected by the miner under the greatest physical disadvantages, more especially when the seam of coal is very thin, and is cut on the "end," to improve its saleable qualities. This "holing," or "baring," or "kirving," or undercutting," is usually performed by about 40 blows per minute from a pick, handled with such experience as to cut 3 to 4 ft. under, at the rate of 1 to 1½ yards lineal per hour, and destroying much of the coal, to make room for the operator, and enable him to work partly into the hole, to produce the requisite depth for a fall. The *speed* and *effort* with which this picking tool is moved, combined with its *weight*, represent the *power of one man*, applied in the shape of "percussive force." and this, under advantageous circumstances, is equal to about *one-sixth of a horse-power*. The miner could not, with his *limited power, force his pick*, or any other shaped tool, *into the coal* as if he were cutting cheese: he is like the mechanic, who has to chip all his iron work with hammer and chisel for want of a planing or slotting machine, and must reduce it by little as best he can, "in lieu" of suitable mechanical expedients to concentrate and apply power in a continuous, undeviating, and determined line. Yet the introduction of planing or slotting machines has not injured the mechanic, nor the morticing machine the joiner; there is ample work which the machine cannot do, and there are innumerable mines where no machinery can compete with the skilled miner. To apply the power of horses in lieu of manu-motive power, even though one horse is as powerful as six men, is practically very difficult. The *power* of *both* is dependent on the produce of cultivated lands; and the fewer horses required the cheaper the necessaries for human sustenance. There is yet a far more effective substitute for the power of both man and horse, which has been inviting our use for centuries, in the form of what GEORGE STEPHENSON conceived to be "bottled up sunshine." A COAL-FED STEAM-ENGINE, of one horse-power, is twelve times cheaper than one animal horse-power, and our obedient servant for 24 hours daily, consuming the produce of uncultivated lands on which the sun shone ages ago. Now, it is desirable that in many favourable circumstances this "undercutting" operation of the miner should be accomplished indirectly by this *steam-power*, and one of the practical methods of accomplishing this object is the subject of present consideration. If one collier had the power of (say) 18 men, and when necessary could make himself 2 ft. high, and hold himself down upon the floor of the mine by pressing his head against the roof, and hold firm in his hand a kind of "cheese scoop" in lieu of a pick, and could force it steadily into the coal at the necessary height from the floor, and to the required depth, he would then be exactly what is in many cases wanted: he would be a travelling morticing machine, and do more in one minute than 700 blows from a hand-wrought pick can do, and would in fairness demand a very stiff wage, which he would undoubtedly obtain. This is what the Iron Man or Hydraulic Coal-Cutter accomplishes. "He" is, if necessary, 2 ft. high, has four legs, of adjustable length; his head is also adjustable to touch the roof, and he weighs 1 ton. He is fed by a 2-in. flexible pipe with sober drink, at 300 lbs. pressure, and at the rate of 30 gallons per minute. This water pressure acts vertically on a 5-in. piston pressing against the roof, and horizontally on one about the same size, reciprocating 18 in., and from 15 to 20 times in a minute. There is a pressure of 5000 lbs. against the roof, and the same pressure acting horizontally, forcing three "cheese scoops" into the coal. These cutting tools are 3 in. wide, and penetrate 4 ft., with a power equal to three horses or 18 men, and this is effected by a consumption of 50 lbs. of coal per hour to feed the boiler of the engine, which makes the water pressure, and pumps the same over and over again. Thus this Automaton Iron Man is dead fast when forcing the cutters into the coal, and only requires to lower his head 1 in. at the return or back stroke, and advance, which he does also self-acting, at its termination, ½ in. to 1 in., and then again he elevates his head and is ready for the next cutting stroke; his sober veins being filled by incompressible if not exhilarating "water," and retained therein by a keep-valve, for the necessary time, enabling him at that moment to defy the roof to crush him.

This *Self-acting Hydraulic Coal-Cutting Machine, or "Iron Man,"* which has now been two years at work, is the miner's best friend: it does not dispense with his labour, but performs for him the undercutting, which is a most laborious operation, either in the end or face of coal, and in a more efficient and economic manner than he can do it himself. The coal so operated on by the machine does not fall forward when becoming detached from the roof, but settles on the lower bed, thereby avoiding serious accidents. The saving in coal alone more than pays for the outlay; and it is practicable to cut with the most perfect ease into the floor of the mine, thus preventing all waste of coal whatever. (*See Fig.* 3.) The size of the coal is improved, the amount of slack is considerably reduced, and a single seam will yield more by 1000 tons of coal per acre than when worked by hand-labour in the usual manner.

The machine undercuts "holes," or "kirves," with a man and boy as attendants, *and completes the work with once going over, at the rate of fifteen yards per hour*, and at any angle and height from floor or rails, being suitable for either "dip" or "rise" workings, and is capable of cutting the thinnest seams. The pressure of water which actuates this apparatus can be obtained either from the stand pipes in the pit, or from pumps attached to any existing engine, or from an engine and pumps specially made for the purpose. The quantity necessary is only what is sufficient to fill the circuit of the pipes, using it over again when desirable, as in the Bramah press. Any idea of a large volume of water being necessary may, therefore, at once be dispelled. There is also no leakage whatever. Each machine uses 30 gallons per minute, at about 300 lbs. pressure, according to the hardness of the coal or mineral to be operated upon. In cutting the shale of the Cleveland ironstone band, a somewhat greater pressure is found to be necessary.

There is no limit to the pressure of water that may be used, nor the distance it may be forced without loss of power, beyond that due to its friction along the pipes. The same water-pressure is also applicable to work pumps and rotative engines for hauling, &c., and other requirements in the mine, at a distance from the engine power. In cases where there is a fall of water (say) of 100 lbs. pressure, it can be "intensified" by a self-acting machine to 400 lbs. pressure to work the coal-cutter, but sacrificing three-fourths of its bulk, which is thereby set free.

The water is supplied in a continuous stream; it is, in fact, the *medium* through which the mechanical power is applied direct from the first coal-fed motor (a steam-engine and pumps), in lieu of the usually developed power derived from vital energy, and applied to the handle of a pick, effecting the desired object by a series of percussive blows or impacts. The power of six men is equal to one horse, and is six times more costly; and the power of one horse steam-motor, or engine, is eighty times cheaper than six men. The machine is about three-horse power, and weighs 1 ton, and will work either right or left. (*See dotted lines on ground plan.*) It is self-acting in all movements, and will ascend the steepest gradients; being simple in all its parts, it is not liable to get out of order, and is easily managed by an ordinary miner, and transported from place to place, on the ordinary rails, about the mine.

Although the length of stroke of each cutting tool is 18 inches, the practical cutting length is 16 in., and, consequently, the three cutters jointly give a total effective depth of 4 ft. at each stroke of the machine, finishing the work as it goes along. The mechanism employed consists of an hydraulic reciprocating engine, adjustable to any height and angle, having a self-acting valve motion. The cylinder is 4½ in. diameter, and l ed with brass, and the piston made tight with ordinary hydraul le r ers, easily renewable. Within the piston-rod is attached the cutt r bar of steel, carrying the tools or cutters. These can be varied in number, to suit the depth to he holed at one operation. The cutting tools are of double sheer steel, easily made, and very strong, and can be removed and replaced in a few moments; they are readily sharpened on an ordinary grindstone. The cutter bar is also removeable when transporting the machine from place to

place, for which purpose the main cylinder is, for the time being, placed longitudinal with the rails. (*See dotted lines in Fig.* 1.)

The machine in operation fixes itself dead fast upon the rails during the cutting stroke, and releases itself at the back or return stroke, and traverses forwards the requisite amount for the next cut, without any manual labour. Should the tools be prevented making the full stroke at one cut, they will continue to make more strokes at the same place, until the maximum depth is attained, when "only" the machine will traverse itself forward the required amount for the next cut. Thus, at *one operation*, a uniform straight depth is attained, parallel with the rails, inducing an even fracture when the coals are brought down, and thereby a straight line for the new coal face. There is no percussive action, either against the roof or into the coal, but simply a concentrated pressure, producing a steady reciprocating motion, at 15 strokes per minute. There is, consequently, no dust or noise, and little wear and tear. For the same reason, when cutting pyrites, the tools throw out no sparks, and the workman can hear any movement in the coal or roof.

The required height from the line of rails in the "holing," "kirving," or "baring," varies in different mines, it follows that the hydraulic cutting cylinder, and its direct-action cutting tools, have sometimes to be arranged *above* the carriage, and sometimes *beneath* the main carriage, or close down upon the rails, as is illustrated in Figures 1 and 2. Figure 1 is the main carriage, with four wheels, far enough apart to allow the machine to be placed longitudinally when being transported from place to place. The screws, Y Y, are for raising and lowering the carriage and its cylinder and cutting tools. The pinion, Z, and the segmental rack, H, regulate the desired angle of the tools cutting into the coal face, and the two nuts at each end of carriage, *x x*, regulate the angle required, when necessary that it shall not be in the same plane as the rails.

A, A, A, are the cutting tools, B the cutter bar, N a guide roller for the same; D is the main cylinder, with its self-acting hydraulic valve motion, which passes a portion of its water alternately above and below the piston of the holder-on, which thus rises and falls without percussion, and follows the uneven line of the roof of mine, so that the required stability is given to the machine for the time being, an instant before the cutters enter the coal. The "holder-on piece" can be any length necessary to bridge over gaps in the roof; it is loose on the pin, F, and droops at its leading end to enable it to ride over the varying projections in roof. The traverse motion is actuated by the pin, *b*, which connects the cutter bar with the piston rod, and at the termination of each end of its stroke actuates the lever, *d*, in both directions, which operates on the pall, *c*, which causes the chain pulley to revolve on the chain, *i*, made fast ahead by an anchor-prop between floor and roof.

In arranging the engine and pumps required to make a "continuous stream" of water pressure for working these machines, it is preferable to have two steam cylinders, so that there be no dead centre. They are constructed to work one, two, or four machines. The pipes for one machine are of 2-in. bore, wrought-iron, a superior quality of gas pipes to stand 500 lbs. pressure, at 3s. 6d. per yard. These pipes are screwed together in the ordinary manner, and adapt themselves readily to the irregularities of the floor of mine. A flexible pipe 1¼-in. bore, suitable for the same pressure, allows the machine to traverse. *The proprietors of this patent beg to inform colliery owners and mining engineers that they are now prepared to supply these machines on reasonable terms, and will treat either for the machines and the absolute use thereof, or for the machines and an annual royalty for such use, and terms may be had on application.*

Machines may now be seen at work in Messrs. LOCKE and Co.'s Kippax Colliery, near Leeds, from whom, or Messrs. CARRETT, MARSHALL, and Co., Sun Foundry, Leeds, sole makers, any further information may be had on application, or leave to inspect at work. They are in operation in Scotland, Northumberland, Yorkshire, and Staffordshire, and in the Cleveland ironstone bed; and are being introduced into the copper mines of Brunswick, and to work in the coal fields of the United States. A working model can any time be seen in operation at the makers', Sun Foundry, Leeds.

UTILISATION OF BLAST-FURNACE GASES.

[*Concluded from the Mining Journal of Aug.* 11.]

Mr. J. E. SWINDELL observed that mention had been made in the paper of a close-topped furnace at Dowlais, from which the gas was carried to a distance of a quarter of a mile before being consumed, and he enquired whether it could be conveyed to as great a distance if required in the mode now described of taking off from open-topped furnaces?—Mr. ADDENBROOKE replied that in the open-topped furnaces the gas could be taken to any distance, according to the power of the chimney-draught, and with the advantage that the working of the furnace would not be affected by any back pressure, whatever might be the distance to which the gas was conveyed. With a more powerful chimney, however, the gas openings would have to be placed rather lower down in the furnace, so as to avoid drawing in air with the gas. In the case of the close-topped furnace at Dowlais that had been named, a portion of the gas taken off was employed near the furnace for burning bricks and calcining ironstone; and the rest of the gas was then conveyed to a distance of about ¼ mile to heat the boilers of the forge and rolling-mill; but the back pressure produced in the furnace top by forcing the gas along such a length of pipe amounted to 3-16 inch of water, and he understood it was intended to employ a fan for drawing off the gas, so as to diminish this back pressure on the furnace.

Mr. W. HADEN enquired whether there would not be some difficulty in replacing the castings forming the gas openings round the neck of the furnace, whenever they required renewal? and whether it would not be advisable to make some provision for replacing them readily in the event of any mishap?

Mr. ADDENBROOKE replied that with the present strong construction of the castings forming the gas openings, of which a full size model was exhibited, it was not expected that there would be any considerable wear, and there was reason to expect they would last quite as long at least as the lining of the furnace; and as they merely took the place of a few courses of lining at the top of the furnace, they could readily be replaced, if requisite, at the time of renewing the lining. The durability of the castings would, of course, depend upon the care with which the furnace was worked, and if there were a flame through the gas openings it would necessarily cause destruction of the iron; but it must be borne in mind that when the working was properly managed, so that a flame was always kept burning out at the furnace top, and the loading of the materials kept up to the proper height above the gas openings, the gas was drawn off through the openings without any flame, because no air was then drawn down from the top to produce flame below the surface of the materials, and, consequently, the castings were not exposed to injury from the passage of the gas through the openings. Even the first gas openings, constructed of only 2-inch cast-iron plates, as a temporary expedient by way of making trial of the new plan, had continued satisfactorily in work for upwards of a year, notwithstanding the very severe test to which they were subjected within three months of being put in, when the whole throat of the furnace had been at a red-heat for two days; and the present castings were so much more massive that they were expected to prove much more durable. On the occasion of putting in the new castings in the second furnace to which the plan had been applied, which had been done about nine months ago, advantage had been taken of an opportunity when work was slack; and the blast being turned off, the furnace stood six days with the charge in it, while the top was taken down sufficiently far to put in the new set of openings, after which the working was continued again without any inconvenience resulting from the stoppage. At present there had been only nine months' actual experience of the durability of the castings; they did not show any injury, and whenever they might require renewal, the cost of replacing them would not be serious, as the iron originally put in would be nearly all recovered in the old castings taken out.

The CHAIRMAN remarked that as the ring of gas openings round the neck of the furnace was composed of separate segmental castings, he presumed it would be practicable at any time to replace a single defective casting without much difficulty; and he enquired what was the weight of each of the castings, and whether they were placed contiguous to one another all round the circle, or whether there was anything interposed between the successive segments?

Mr. ADDENBROOKE replied that the castings weighed nearly 1 ton each, and were placed close together round the furnace-throat without anything between them; and for taking out any one of the castings it would only be necessary to take down the furnace top immediately above that particular casting, so as to allow of lifting it out by a crane, and putting in another casting in its place.

Mr. C. P. SANDBERG remarked that the utilisation of the waste gas from blast-furnaces had been clearly proved to be beneficial, even where fuel was cheap; but the difficulties by which it was attended—irregularity in the working of the furnace, increased consumption of fuel per ton of iron produced, and liability to explosions—had to be carefully guarded against, otherwise the result would be a loss instead of a saving.

On the Continent and in Sweden the waste gas had been utilised for 20 to 30 years past. In Sweden Prof. N. G. Sefstrom, of the School of Mines at Fahlun, had been the first to employ the gas for the calcining kilns and hot-blast stoves. The gas was taken off through an opening in the wall of the furnace, about 5 ft. below the top, and the furnace top was left open. The hot-blast stove was placed at the level of the furnace top; and the calcining-kiln was also placed in a high position, in order that the gas might not have to be drawn down to a much lower level, which was to be avoided on account of the small pressure of the gas. In some places a vertical cylinder of nearly the same diameter as the furnace-mouth was inserted in the top of the furnace, for taking off the gas from the top, thus obtaining a higher pressure; while the surplus gas was allowed to escape through the annular space between the cylinder and the furnace wall. This plan had been applied to charcoal-furnaces with but little difficulty, so long as the gas was not required to be drawn down from the furnace top to a lower level; but considerable difficulties had arisen when the fireplace where the gas had to be burned was situate down at the level of the tuyeres, in which case the necessary power for drawing the gas down had not been obtained, even with the assistance of an ordinary large chimney; and the result had been a greater consumption of fuel in the furnace instead of a saving. In order to ensure the gas being drawn down, it had been found advantageous to have a pressure of gas in the tube of not less than ½ in. of water at the furnace top and 1-10th in. near the fireplace at the level of the tuyeres.

In conveying the gas through tubes from the furnace top to the fireplaces it was found better to have a positive pressure or plenum inside the tubes; so that the small openings for leakage round the valves, which could scarcely be avoided, might allow the gas to escape, instead of drawing air into the tubes. In the fireplace also the combustion was better effected when the gas was delivered there by pressure than when drawn down by means of a draught. It had also been found necessary to avoid the horizontal gas tube at the top of the furnace, because it was liable to become filled up with dust deposited there from the gas taken off; and it was desirable to conduct the outer end of the gas tube into a water-cistern, which acted both as a receptable for dust and also a safety-valve.

In coke-furnaces the means of obtaining the requisite pressure in the upper part of the furnace for forcing the gas down from the furnace top had generally been by working the furnace with a closed top; but in charcoal-furnaces the charge itself acted as a sufficient cover to close the furnace top, the ore being crushed to a fine state; and in these furnaces, therefore, it was sufficient to lower the opening for the escape of the gas, while the furnace top was left open. The close-topped furnaces were worked in many localities in England and on the Continent, while the open-topped furnaces were employed in some parts of France, Germany, and Sweden; and in the Swedish furnaces charcoal was used exclusively. In the case of six open-topped charcoal-furnaces in Sweden, of which he had had the management from 1856 to 1860, the hot-blast stoves were removed from the top of the furnaces down to the level of the tuyeres, and the necessary pressure of the gas was obtained by lowering the gas opening down to 14 ft. below the top, the height of the furnaces being 42 feet. No chimney was used in connection with the stoves, and no loss of fuel or other objection was caused by taking off the gas so low down in the furnace.

In the plan described in the paper for taking off the waste gas, the use of a chimney draught for drawing down the gas from the furnace top had been carried out to a much greater extent than he had ever seen successfully accomplished before, the gas openings being only 4 feet below the furnace top, which was left entirely open, and the gas being drawn down to the level of the tuyeres entirely by the force of the chimney draught. Such an arrangement appeared a retrograde movement in the principle of taking off the waste gas; but having had the pleasure of seeing the working of this plan at the Rough Hay Furnaces, he had found that it proved completely successful in practice. The supply of gas at the boilers appeared to be plentiful, and the combustion was well regulated; and the whole arrangement was well worthy the attention of everyone connected with the working of blast-furnaces. He thought, however, that with the gas openings situated at only 4 ft. depth below the open furnace top, and with such a large chimney for drawing off the gas, there would be need of special care to keep the furnaces at all times well filled and regular in the level of the charge; otherwise air would be drawn down from the top, and entering with the gas into the pipes would cause explosion. The reason assigned for placing the gas openings so near the top of the furnace was that the consumption of fuel had been found to be increased when the gas was taken off at a lower level; but in this respect the experience of the furnaces referred to in the paper differed from that of the Swedish charcoal furnaces, as well as the continental coke furnaces, where the gas was taken off at a much greater depth below the top without increasing the consumption of fuel.

Mr. ADDENBROOKE observed that, though the use of a chimney for drawing off the gas from a blast-furnace appeared to be little known in connection with the Swedish furnaces, it was by no means new in this country, having been employed previously for furnaces in Staffordshire, as well as in the Yorkshire and Welsh districts. The level at which the gas was drawn off from the furnace had been found in his own experience to be an all-important point; and he did not understand how this could have been found a matter of indifference in the Swedish furnaces. As regarded the liability to explosion in taking off the gas by the mode described in the paper, he had not found there was any liability to explosion, unless through gross carelessness and mismanagement. In Sweden he understood there had been several explosions, and nine or ten hot-blast stoves had been split by explosions; and he thought this was to be accounted for by the plan of taking off the gas, having a plenum of pressure to force the gas down from the furnace top, instead of a chimney draught to draw it down; so that, whenever the stoves were standing idle, there was a liability of some gas being still forced into them through the leakage of the valves; and as there was no draught to carry it off, this would hang in the top of the stoves, and form an explosive mixture with the air, and then explosion would ensue when a light was applied to it. But with the chimney draught as employed at his own works, the regulations were that the draught was always to be put on the stoves before the gas was admitted, so that there was no opportunity for any explosive mixture to be formed; and he had accordingly had scarcely any accidents by explosion in the use of waste gas for the boilers and hot-blast stoves.

Mr. JOHN JONES enquired whether in taking off the waste gas by the plan described in the paper the production of pig-iron by the furnaces had been greater or less than before the gas was taken off?

Mr. ADDENBROOKE replied that the production of pig-iron had certainly been found to be increased since the waste gas had been taken off, the make of each furnace having now got up to more than 200 tons per week, instead of the former make of only 150 or 160 tons per week. He did not consider, however, that the whole of this increase of make was to be attributed to taking off the waste gas, as he thought it was partly due to the use of the new gun-metal tuyeres, which had recently been adopted for blowing the furnaces, and which formed the subject of another paper at this meeting. Another advantage which had been experienced was that the quality of the iron made was very much more regular than before the gas was taken off from the furnaces.

The CHAIRMAN moved a vote of thanks to Mr. Addenbrooke, which was passed.

EXCAVATING MACHINERY.—At a recent meeting of the French Society of Civil Engineers the result of some experiments with Messrs. Frey Brothers and Sayn's excavating machinery were given. The cylinder of the engine forming the motive-power was 7·4 in. diameter, with a stroke of 14·2 in., and it was supplied with steam at a pressure of 120 lbs. per square inch, cut off at two-thirds of the stroke. The speed of working was 140 revolutions per minute, and this gave a speed to the bucket-chain of 1·47 ft. per second, the number of buckets passing in one minute being 30. The capacity of each bucket was 1·41 cubic foot, and if each bucket had been completely filled the quantity excavated at the above rate of working should, consequently, have been 42·3 cubic feet per minute, or 94 cubic yards per hour. During the trial of 91 minutes, however, the quantity excavated was 76·4 cubic yards—this being at the rate of 50·38 cubic yards per hour, or 503·8 cubic yards per day of 10 working hours. The amount actually excavated was thus about 54 per cent. of that theoretically due to the speed and capacity of the buckets. The earth was lifted 4 yards, and moved 12 yards horizontally, yet the cost was only about 1d. for each cubic yard excavated.

MANUFACTURE OF SALT.—Mr. D. Hall, of Wharton, Cheshire, has patented an invention which consists in an improved method of feeding the fires with small coal; an improved method of preventing the formation of pan-scale on the bottoms of salt pans, and a mode of removing the salt into pans and wagons.

SALES OF COPPER ORES.

COPPER ORES SOLD AT THE SWANSEA TICKETINGS FOR THE QUARTER ENDING JUNE, 1866:—

Mines.	Tons.	Amount.
BRITISH.		
Berehaven	1861	£13,061 14 0
Ballycummisk	89	617 8 0
Great Laxey	147	494 5 0
Cappagh	68	388 0 6
Total	2165	£14,561 7 6
COLONIAL.		
Moonta	3853	£64,563 7 0
Cape	923	19,705 2 0
Wallaroo	2240	17,188 1 0
Yanganooka	292	3,809 17 6
Concordia	160	2,030 8 6
Gwalia	162	2,007 5 6
Newfoundland	41	342 7 0
N. T. M.	19	293 12 0
African	13	237 7 6
Australian	5	116 5 6
Total	7708	£110,293 14 6
FOREIGN.		
Cobre	2204	£24,863 13 6
Californian	2282	18,771 9 6
Leghorn	315	2,262 2 6
Genoa	265	1,501 1 0
Var	74	1,080 8 0
Del Soto	81	1,005 5 0
Terricio	31	341 0 6
Casali	27	234 4 6
Hoz de Barcena	23	207 11 6
Victor Emanuel	27	174 13 6
Norway	9	152 17 6
Gijon	25	68 15 0
Pomona	1	23 18 0
Spanish	1	13 3 6
Azambugeira	1	7 18 0
Total	5366	£50,708 1 6
RECAPITULATION.		
Colonial	7708	£110,293 14 6
Foreign	5366	50,708 1 6
British	2165	14,561 7 6
Sundries	39	678 18 0
Total	15,278	£176,243 1 6

COMPANIES BY WHOM THE ORES WERE PURCHASED.

Copper Miners' Company	1659	15,362 1 3
Freeman and Co.	668	11,745 6 7
P. Grenfell and Sons	1592	11,914 4 0
Sims, Willyams, and Co.	1199	17,703 4 7
Vivian and Sons	2660	28,121 7 6
Williams, Foster, and Co.	2819	34,028 10 1
British and Foreign Copper Company	154	2,626 16 9
Mason and Elkington	894	10,237 2 3
Bankart and Sons	729	7,764 2 3
Charles Lambert	1296	15,092 8 6
Sweetland, Tuttle, and Co.	599	7,810 8 6
Penclawdd Copper Company	720	6,752 0 0
Crown Copper Company	279	2,095 10 3
Total	15,278	£176,243 1 6

SALES OF COPPER ORES.

COPPER ORES SOLD AT THE CORNWALL TICKETINGS FOR THE QUARTER ENDING JUNE, 1866:—

Mines.	Tons.	Amount.
Devon Great Consols	5925	£23,689 13 6
Clifford Amalgamated	3442	12,897 19 6
South Caradon	1432	11,472 3 0
Wheal Seton	2221	9,073 19 6
West Seton	1430	6,784 19 6
Marke Valley	1260	4,197 0 6
East Caradon	914	3,478 12 0
Wheal Friendship	485	3,150 0 0
Prosper United	1093	3,079 4 6
Wheal Basset	485	2,803 19 6
East Carn Brea	775	2,773 3 6
Carn Brea	607	2,684 5 6
Fowey Consols	610	2,585 5 0
West Basset	547	2,509 3 0
South Crofty	518	2,290 9 0
Brookwood	536	2,163 14 0
Rosewarne United	327	2,084 0 0
West Tolgus	530	2,081 8 0
Hingston Down	603	1,991 5 6
North Treskerby	431	1,931 19 0
West Damsel	586	1,839 14 0
Phœnix	762	1,737 11 6
Botallack	113	1,558 15 6
Par Consols	297	1,487 13 6
Wheal Rose	401	1,431 11 0
Craddock Moor	384	1,418 9 6
Bedford United	821	1,383 11 6
Devon and Cornwall	526	1,332 2 6
Dolcoath	251	1,308 10 6
East Pool	412	1,269 16 0
East Basset	271	1,198 11 6
Bampfylde	145	1,138 7 6
Glasgow Caradon	301	1,116 19 0
East Rosewarne	147	1,071 7 9
Great South Tolgus	262	1,000 19 6
Okel Tor	301	965 10 6
Carn Camborne	260	936 2 0
Grambler and St. Aubyn	139	821 5 0
West Caradon	161	713 17 6
Wheal Margery	256	705 8 0
Wheal Polmear	102	668 11 0
Wheal Polmear	109	670 10 0
Great Wheal Busy	314	662 14 0
Great North Downs	225	658 15 0
Wheal Emma	113	636 8 6
East Wheal Grenville	174	619 5 6
South Frances	132	618 12 0
Hallenbeagle	197	615 7 6
Rosewarne Consols	96	520 12 6
New Wheal Martha	326	494 18 0
East Wheal Russell	128	461 0 6
Prince of Wales	46	440 5 0
Levant	93	425 1 6
South Condurrow	104	405 6 6
North Roskear	97	402 4 6
Tolcarne	120	381 18 0
Mellanear	115	376 10 6
Wheal Curtis	104	355 6 0
Gunnislake	100	351 10 0
Great Brigan	57	350 11 0
West Maria and Fortescue	150	350 8 0
Copper Hill	110	317 13 0
South Tolgus	76	311 5 0
New Rosewarne	62	306 7 0
Nangiles	50	296 4 0
Wheal Crelake	80	274 0 0
Durrieu's Precipitate	14	268 18 6
Wheal Crebor	86	267 3 0
Tresavean	91	251 0 0
Tincroft	76	234 18 0
South Dolcoath	42	232 2 0
St. Day United	53	228 6 6
Pendeen Consols	70	218 15 0
Boscaswell	37	206 5 6
Sortridge Consols	56	199 13 0
North Grambler	42	196 6 0
North Basset	56	195 8 0
New East Russell	33	173 5 0
South Carn Brea	62	172 9 0
North Downs	40	170 0 0
Wheal Union	23	158 14 0
Pendarves United	43	155 14 6
Hawkmoor	48	139 16 0
Great Work	25	133 14 6
New Treleigh	42	131 5 0
Wheal Buller	42	116 17 0
Crowan Consols	33	106 12 0
West Condurrow	21	102 7 6
North Wheal Robert	35	101 10 0
Lady Bertha	55	94 17 6
Kelly Bray	35	90 2 6
West Stray Park	19	87 8 0
North Crofty	40	75 12 6
Wheal Edward	29	73 4 6
Wheal Grenville	16	70 8 0
Wheal Agar	17	69 14 0
Opie's Precipitate	3	63 0 0
North Pool	16	59 4 0
Pursedon	20	57 0 0
South Wheal Basset	11	51 19 6
Wheal Harriett	14	50 15 0
Roskear	12	50 14 0
Higgins's Ore	21	45 13 6
South Crinnis	16	38 16 0
Tolvadden	11	36 6 0
Collacombe	9	20 18 6
Mayne's Ore	10	12 10 0
Boscawen	6	10 16 0
Buckingham's Ore	14	8 1 0
Great Crinnis	1	7 12 6
Pembroke	4	6 10 0

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P. Grenfell and Sons	2960	16,155 14 2
Sims, Willyams, and Co.	4027	14,247 15 6
Williams, Foster, and Co.	5631	27,757 5 8
Mason and Elkington	3763	15,345 5 4
Bankart and Son	2177	8,029 3 1
Copper Miners Company	2592	8,477 6 3
Charles Lambert	3417	9,980 3 7
Newton, Keates, and Co.	301	1,321 19 0
Sweetland, Tuttle, and Co.	1207	3,857 11 7
Penclawdd Copper Company	83	293 3 4
Hadland and Co.	603	1,674 16 0
Crown Copper Company	880	2,920 13 9
Total	34,466	£145,455 19 6

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